Commissioning of the LHCb's first level trigger

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on behalf of the LHCb Real Time Analysis Project
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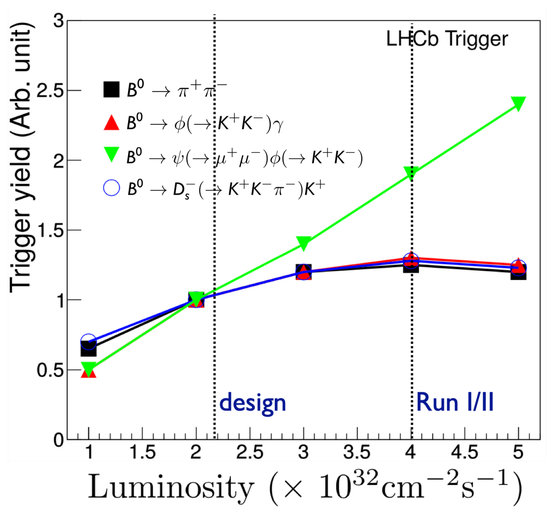
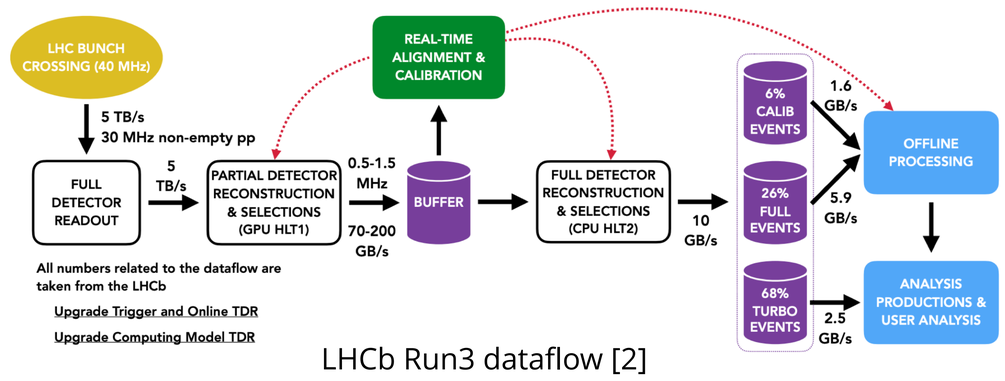
Triggering at LHCb: Real Time Analysis

- LHCb major upgrade to record 25 fb^{-1} in Run3+4
- Luminosity increased by a factor 5 compared to Run1-2: $\mathcal{L} = 2 \cdot 10^{33}\, cm^{-2}s^{-1}$
- Removing hardware trigger to increase efficiency of hadronic channels by a factor 2 to 4
- **Challenge**: full reconstruction of events at 30 MHz LHC non-empty pp collision rate
- The Real Time Analysis project: a full software trigger based on reconstruction, alignment and calibration in real time



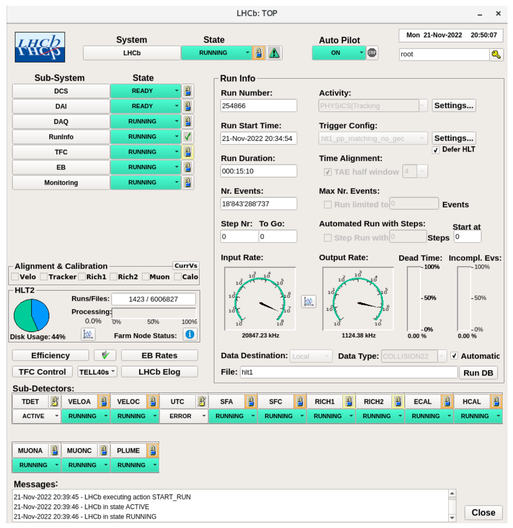
Trigger yield dependence on instantaneous luminosity [1]



LHCb Run3 dataflow [2]

HLT1 performance

- Major RTA milestone to take data at full LHC rate
- Online reconstruction performed with all subdetectors included (except UT)
- Can run the full tracking despite missing UT thanks to 2 new algorithms



The LHCb Experiment Control System main panel.

- Selecting events with HLT1 trigger lines for different physics purposes
- Goal achieved to reduce the input rate reaching 1 MHz of output

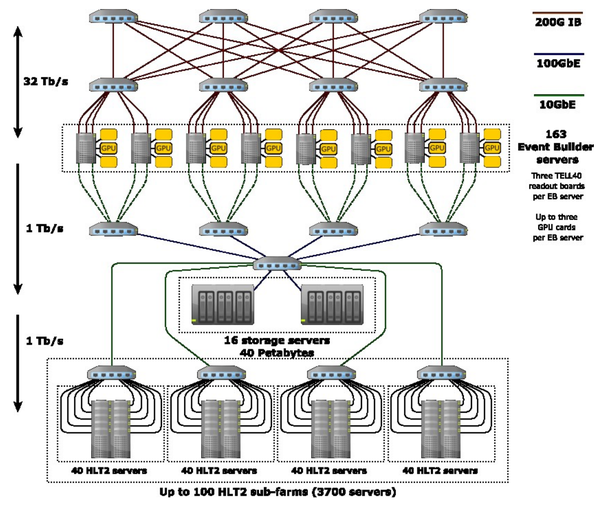
The first high level trigger: HLT1

- First high level trigger (HLT1) fully based on Graphics Processing Units (GPU): the Allen project [3]
- **Goal:** take data at 32 Tbit/s and reduce input rate by a factor 30

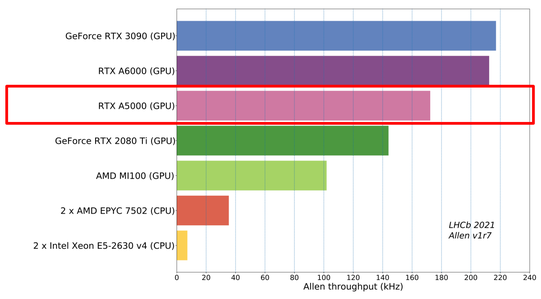
Why GPUs?

- Parallelize the reconstruction per event and per track
- Event builder servers provide 3 GPU slots: compact system and cost savings

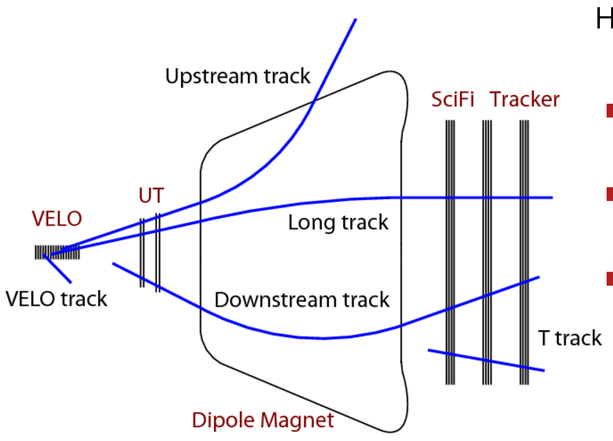
- NVIDIA RTX A5000 default GPU card to handle ~170 kHz of throughput
- Around 160 GPUs to deal with 30 MHz LHC pp collision rate



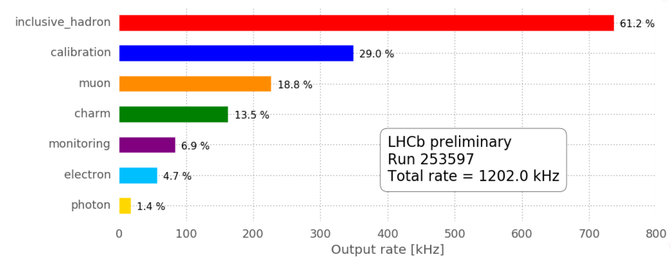
Run3 data acquisition system [4]



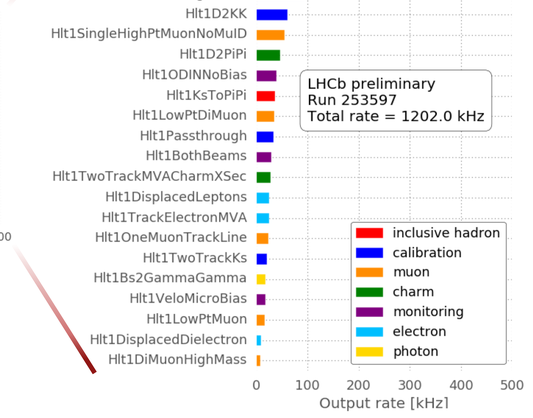
HLT1 throughput for different GPU cards [5]



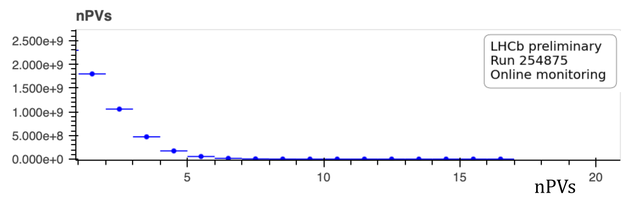
- HLT1 heavily based on tracking (Velo, UT and SciFi)
- Different type of tracks are reconstructed
- Information from muon and calorimeter system to reconstruct and identify muons and electrons/photons

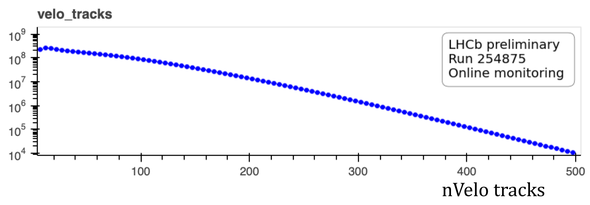


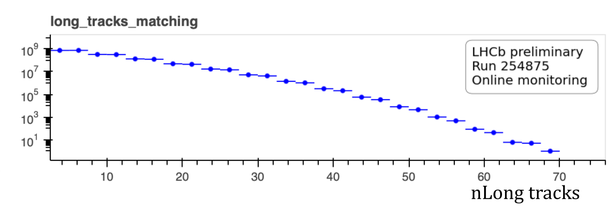
Output rate of HLT1 trigger lines.

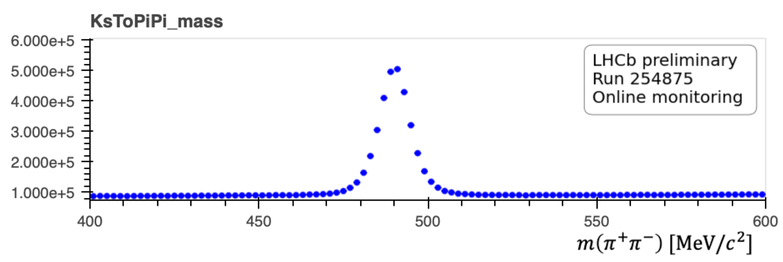


- Online monitoring of number of tracks and primary vertices
- First online mass peak in the monitoring: $K_S^0 \to \pi^+\pi^-$









Online monitoring of HLT1 tracking and invariant masses.

Conclusion

- Long year of commissioning with many goals achieved:
  HLT1 trigger running at the LHC full input rate performing reconstruction and selection
- Extending the HLT1 capabilities by doubling the number of GPUs per server

References

[1] A. Piucci, "The LHCb Upgrade," J. Phys. Conf. Ser. 878, no.1, 012012, 2017.
[2] LHCb Collaboration, "RTA and DPA dataflow diagrams for Run 1, Run 2, and the upgraded LHCb detector", LHCb-FIGURE-2020-016, 2020.
[3] LHCb Collaboration, "LHCb Upgrade GPU High Level Trigger Technical Design Report", LHCB-TDR-021, 2020.
[4] Aaij R et al. (LHCb Collaboration) ,"A Comparison of CPU and GPU Implementations for the LHCb Experiment Run 3 Trigger", Comput. Softw. Big Sci. 6, 2022.
[5] LHCb Collaboration, "Performance of the GPU HLT1 (Allen)", LHCB-FIGURE-2020-014, 2020.
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